C L I N I C A L I N V E S T I G A T I O N S S E R I E S

Pulse oximetry: what the nurse needs to know


Rebecca Myatt
Nurse case manager (thoracic surgery), Guy’s Hospital, Guy’s and St Thomas’ NHS Foundation Trust, London, England

Correspondence
Rebecca.Myatt@gstt.nhs.uk

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None declared

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Rationale and key points
Measurement of peripheral oxygen saturation (SpO$_2$) is used to identify early hypoxia in patients and evaluate the effectiveness of oxygen therapy. Nurses should be aware of the procedure for using a pulse oximeter to measure SpO$_2$ levels and the normal range for SpO$_2$ readings.

- A pulse oximeter is used to measure SpO$_2$ levels, and involves placing a probe on the patient’s finger, toe or ear lobe.
- A SpO$_2$ level of less than 90% is a clinical emergency. If the SpO$_2$ level is below 94%, the nurse should assume the patient is hypoxic until proven otherwise, and therefore they may require supplemental oxygen administration.
- Nurses should be aware of the factors that might affect SpO$_2$ readings, including anaemia, peripheral vasoconstriction, dark skin tone and skin discolouration.

Keywords
hypoxia, oxygen saturation, oxygen therapy, pulse oximetry, respiratory assessment

Learning outcomes
After reading this article you should be able to:
- Understand the clinical importance of undertaking pulse oximetry.
- Demonstrate the correct procedure for using a pulse oximeter to measure a patient’s peripheral oxygen saturation (SpO$_2$) level.
- Explain the rationale for pulse oximetry, and the SpO$_2$ levels at which supplemental oxygen administration is required.

Pulse oximetry
A pulse oximeter measures the percentage of haemoglobin in the blood that is saturated with oxygen (Randle et al 2009). Since it detects the saturation peripherally on a patient’s finger, toe or ear lobe, the measurement is recorded as SpO$_2$ (World Health Organization (WHO) 2011a). Pulse oximetry is used to identify early hypoxia in patients and evaluate the effectiveness of oxygen therapy (Randle et al 2009). The SpO$_2$ is also recorded as part of a holistic physical assessment of a patient, along with temperature, pulse, respiration rate and blood pressure, to provide baseline measurements for future reference.

Related physiology
Oxygen is transported around the body attached to haemoglobin, which is contained in red blood cells. One molecule of haemoglobin can carry up to four molecules of oxygen, at which point it is described as saturated (WHO 2011a). Oxygen and haemoglobin are combined as they pass through the capillaries in the lungs. The heart pumps blood around the body to deliver oxygen to the tissues. All organs in the body require oxygen for metabolism, but the brain and heart are particularly sensitive to reduced oxygen levels; lack of oxygen to these organs for a few minutes is fatal (WHO 2011a).

Blood saturated with oxygen is a different colour from blood depleted of oxygen (Dougherty and Lister 2015). Arterial blood is saturated and bright red, while venous blood is depleted and dark red, as a result of the difference in haemoglobin saturation
Pulse oximetry uses this principle to provide a measurement of SpO₂. A probe, which contains light emitting diodes (LEDs) that emit both red and infrared light and a light detector (photo detector), is placed where a pulse can be detected – on the patient’s finger, toe or ear lobe (WHO 2011a). The light shines through the tissues of the body and measures the difference in colour between oxygenated and deoxygenated blood (Dougherty and Lister 2015). Deoxygenated haemoglobin absorbs more red light, whereas oxygenated haemoglobin absorbs more infrared light (Olive 2017). A pulse oximeter takes multiple measurements every second and calculates the ratio of red to infrared light to give a SpO₂ reading of the peripheral oxygen saturation (Olive 2017).

**Undertaking pulse oximetry**

**Preparation and equipment**

» The nurse should ensure that the appropriate equipment is available including:

– Alcohol gel, depending on local policy.
– Pulse oximeter.
– Nail varnish remover, if necessary.

» The nurse should explain the procedure to the patient and obtain verbal consent.

» The nurse should choose a site to apply the probe. This will depend on the patient’s condition and the length of time monitoring is required. A finger is the usual site for pulse oximetry; however, the ear lobe or toe may be used in certain circumstances, for example if there is suboptimal peripheral blood flow to the patient’s finger.

» The nurse should ensure that the site selected to obtain the reading is clean and that the skin appears well perfused. Remove nail varnish if necessary. If the patient has cold peripheries, these may need warming – the nurse should attempt gentle rubbing to encourage vasodilation (Hough 2014).

» If the patient requires long-term monitoring, the nurse should check the site regularly to prevent the development of pressure ulcers, and rotate the probe to other sites.

» If performing continuous assessment, the nurse should avoid the arm used for blood pressure monitoring. This is because inflation of the blood pressure cuff will interrupt the pulse oximeter signal.

**Procedure**

1. Decontaminate your hands, either using alcohol gel or soap and water, in accordance with local policy.
2. Switch the pulse oximeter on. It might need to go through calibration and internal checks before a reading can be obtained. To ensure the reading is accurate, follow the manufacturer’s guidelines.
3. Check that the probe light is illuminated.
4. Position the probe carefully on the selected site, ensuring it is connected to the oximeter and it fits the patient securely, without being too tight or too loose. Ensure it is the correct probe for the site used, because using an incorrect probe will lead to inaccurate readings (Olive 2017).
5. Ensure the probe is placed symmetrically on the patient’s finger. If using the ear lobe, check that it is suitably vasodilated; it should appear red rather than pale (Barnett et al 2012).
6. Encourage the patient to keep the finger as still as possible to ensure an accurate reading. The patient may need to rest the hand down gently to reduce motion interference (Olive 2017).
7. The pulse oximeter may take several seconds to detect the patient’s pulse and calculate the oxygen saturation. The time between applying the probe and an accurate reading can be up to 30 seconds (Hough 2014). Without a detectable pulse signal, the reading will not be accurate.
8. When the pulse oximeter probe has detected a strong pulse, oxygen saturation and pulse rate will be displayed on the monitor (Figure 1). You may check the manual pulse to ensure it correlates with the pulse strength signal and pulse rate on the oximeter (Olive 2017).
9. If the patient’s SpO₂ level is satisfactory, reassure the patient, and record the SpO₂ level, along with details of supplemental...
oxygen administration and the mode of delivery.

10. If the patient’s $\text{SpO}_2$ level is a cause for concern, for example lower than expected, seek advice from senior nursing or medical personnel and document the information. Repeat the investigation and instigate appropriate treatment, such as prescribed oxygen therapy, observing the patient throughout.

11. Clean the probe according to the manufacturer’s instructions.

**Pulse oximetry readings**
The pulse oximeter measures two numerical values:

- The oxygen saturation of haemoglobin in arterial blood, which is shown as a percentage. Some pulse oximeters give an audible signal that varies in pitch according to the $\text{SpO}_2$ level. A falling pitch indicates falling oxygen saturation (WHO 2011a). A patient with no known respiratory problems should have a $\text{SpO}_2$ of 95-100% (WHO 2011a).

- The pulse rate, which is displayed in beats per minute. Some pulse oximeters display a pulse waveform that illustrates the strength of the pulse detected, and therefore how well the tissues are perfused (WHO 2011a).

**Decreased $\text{SpO}_2$ levels and critical values**
Oxygen saturation levels of less than 90% are a clinical emergency (WHO 2011a). If the $\text{SpO}_2$ level is below 94%, assume the patient is hypoxic until proven otherwise (WHO 2011b). It is important that the nurse assesses whether the problem is related to the patient or the equipment (WHO 2011b). Peripheral vasoconstriction, chronic obstructive pulmonary disease (COPD) and cardiac arrhythmias can cause the reading to be lower than expected. If there is any doubt about the accuracy of the reading, the nurse should rely on their clinical judgement and clinical observations, rather than the pulse oximeter. The nurse can check the function of the probe by placing it on their own finger.

If the patient’s $\text{SpO}_2$ is below 94% and suboptimal peripheral circulation and cardiac arrhythmias have been eliminated as a cause, supplemental oxygen administration is required. Oxygen should be prescribed to achieve a target saturation of 94-98% for most acutely ill patients, or 88-92% for patients at risk of carbon dioxide retention, such as those with COPD (O’Driscoll et al 2008). Oxygen should always be prescribed or ordered on a designated document, except in emergencies when it should be given first and the relevant documentation completed later (O’Driscoll et al 2008). Arterial blood gas recordings may also be required.

**Increased $\text{SpO}_2$ levels**
Carbon monoxide exposure from cigarette smoke, car exhaust fumes or fires, will lead to the uptake of these molecules in preference to oxygen (Dougherty and Lister 2015). Carbon monoxide binds to haemoglobin approximately 200 times more strongly than oxygen. Once combined with haemoglobin it forms carboxyhaemoglobin, and oxygen molecules are prevented from binding to haemoglobin (Marieb 2011). Since carboxyhaemoglobin is also bright red, it can lead to a significant overestimation of oxygen saturation when using pulse oximeters (Dougherty and Lister 2015). Arterial blood gas monitoring is required in patients with significant carbon monoxide exposure.

**Factors affecting pulse oximetry**
The patient must have sufficient perfusion in the probe site to enable the oximeter to calculate the difference in blood flow between full and empty capillaries (Howell 2002). Measurements may not be precise in patients with a weak or absent peripheral pulse, hypotension, hypovolaemia,
hypothenmia or cardiac arrest (Howell 2002). Pulse oximeter readings may be affected in patients with anaemia, dark skin tone, skin discolouration or jaundice; however, this is rarely clinically significant (Olive 2017). Patients with anaemia may have high oxygen saturation but inadequate amounts of oxygen reaching the tissues, because of a lack of haemoglobin to transport it (Dougherty and Lister 2015). Table 1 describes other factors that may affect pulse oximeter readings.

**Advantages and limitations**

Measurement of SpO$_2$ is quick, painless and non-invasive. It can be used on a continuous basis and is reliable if performed correctly on a patient with sufficient peripheral blood perfusion. The accuracy of pulse oximeters is limited below SpO$_2$ readings of 70% (Barnett et al 2012). Pulse oximeters cannot provide information about respiratory rate, tidal volume, cardiac output, efficiency of oxygen delivery to the tissues, oxygen consumption, adequacy of ventilation or haemoglobin concentration (WHO 2011a). To ensure consistency, the pulse oximeter must be serviced according to the manufacturer’s instructions by a trained medical engineer. Injury to the patient’s tissues can occur at the measuring site as a result of probe misuse; for example, pressure ulcers may develop from prolonged application or electrical shock, or burns from the substitution of incompatible finger probes (EBME 2014).

**Conclusion**

SpO$_2$ is a safe, cheap and reliable method of obtaining information about the respiratory status of most patients. Patients with underlying co-morbidities, low haemoglobin or extremely low SpO$_2$ levels require more invasive monitoring to provide accurate information about their circulating oxygen levels.

<table>
<thead>
<tr>
<th>TABLE 1. Factors affecting pulse oximeter readings</th>
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<tbody>
<tr>
<td><strong>Factor</strong></td>
</tr>
<tr>
<td>Dirty sensor</td>
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<tr>
<td>Dried blood</td>
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<tr>
<td>Dark nail varnish</td>
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<tr>
<td>False nails</td>
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<tr>
<td>Dark skin tone or skin discolouration</td>
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<tr>
<td>Tremor, rigours, shivering and movement. This makes it difficult for the probe to pick up a signal</td>
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<tr>
<td>Suboptimal peripheral blood flow to the patient’s finger – no signal will be detected if the patient is very cold and experiencing peripheral vasoconstriction</td>
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<tr>
<td>Pulse volume – the pulse oximeter detects pulsatile flow; if the patient has an arrhythmia (such as atrial fibrillation), or hypovolaemic shock, or if the cardiac output is low, it will not pick up a signal</td>
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<tr>
<td>Bright light, such as in the operating theatre or direct sunlight</td>
</tr>
</tbody>
</table>

(World Health Organization 2011a, Dougherty and Lister 2015)

**References**


